Shifts of Critical Personnel in Network Centric Organizations

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ABSTRACT: *Identifying critical personnel has been a problem of interest for sometime as organizations seek to optimize their advantage and disrupt their adversary. This problem has become more difficult with the increasing use of network centric organizations as these organizations have flexible structures that can produce significant shifts of critical personnel. A shift of critical personnel is a change of who is critical within an organization over time. Traditional social network analysis has identified critical personnel using measures applied to static structure. This research adds the process of network change to better understand when shifts of critical personnel may occur. Theory and application are discussed.*

1. Introduction

1.1 Network Centric Organizations: Organizational Design to Match Change

The world has changed drastically in the last decade. From a military perspective, current operations are characterized by rapidly changing and uncertain conditions. Not only has the nature of warfare changed through the use of advanced weaponry and the tactics of terrorism but the U.S. military is increasingly involved in peacekeeping and humanitarian aid responsibilities. In addition, joint and coalition operations are progressively employed to combat terrorism and to perform the various non-combat responsibilities. These joint and coalition operations provide for interagency cooperation leading to shared intelligence and joint tactical operations – capabilities that are considered essential for quick and effective terrorism response. Military organizations must be highly adaptable in order to quickly and effectively shift between warfighting, peacekeeping and humanitarian requirements.

Military organizations have increasingly employed network forms of organizational design in light of the changing and uncertain operating conditions that have fueled the need for learning, adaptability and resiliency (Powell, 1990; Ronfeldt & Arquilla, 2001). Network centric organizations are characterized by flexibility (Nohria & Eccles, 1992), decentralization (Arquilla & Ronfeldt, 2001), differentiation (Baker, 1992), diversity (Ibarra, 1992), lateral cross-functional ties (Baker, 1992) and redundancy (Ronfeldt & Arquilla, 2001). Thus these organizational forms offer many advantages in high velocity environments. Advantages include communication speed and richness (Powell, 1990), knowledge transfer (Podolny & Page, 1998), reduction of uncertainty (Powell, 1990), cross-functional collaboration (Baker, 1992), greater collective action (Powell, 1990) and quick and effective decision-making (Kanter & Eccles, 1992). As Kanter and Eccles (1992) point out, networks are contexts for action. The actions of a network centric organization lead to a dynamic,

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14. ABSTRACT
Identifying critical personnel has been a problem of interest for sometime as organizations seek to optimize their advantage and disrupt their adversary. This problem has become more difficult with the increasing use of network centric organizations as these organizations have flexible structures that can produce significant shifts of critical personnel. A shift of critical personnel is a change of who is critical within an organization over time. Traditional social network analysis has identified critical personnel using measures applied to static structure. This research adds the process of network change to better understand when shifts of critical personnel may occur. Theory and application are discussed.

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evolutionary structure. The network is flexible, ever-changing and hopefully responsive to the environment.[1]

1.2 Identification of Critical Personnel in Network Centric Organizations: Shifts of Criticality

Identifying critical personnel in organizations is a problem that has engendered the interest of practitioners and social network researchers for years. Solutions to the identification problem can be applied both to an organization and its adversary. Internal to an organization, solutions have implications such as sustaining or increasing performance and protecting against risk. Externally, solutions have implications such as destabilizing the enemy and decreasing the adversary's performance.

A shift of critical personnel is a change of who is critical within an organization over time. Shifts of critical personnel are adaptive and resilient responses in the face of change. Such realignment of roles and responsibilities may promote learning within the organization as the internal coordination among members brings together varying expertise and knowledge to deal with the dynamic challenges. Shifts of critical personnel can impact the potential learning, adaptability and resiliency of the organization and it is important to identify who is important when or under what conditions so that opportunities and risks can be managed.

As previously noted, network forms of organizing have been increasingly used in high velocity environments. This is mainly due to other organizational forms, such as hierarchies, struggling to perform in the same environment (Powell, 1990; Ronfeldt & Arquilla, 2001). The usefulness of network centric organizations in highly volatile and uncertain environments – namely the ability to enhance learning, adaptation and resiliency – also creates interesting problems in the identification of critical personnel and in the leadership of such organizations. Particularly, the difficulty lies in the fact that learning, adaptation and resiliency are all dynamic, evolutionary capabilities. With changing environmental conditions and changing organizational structure, critical personnel are now moving targets as shifts may occur more frequently. In other words, the identification of critical personnel in network centric organizations is not a static problem but an evolutionary one. For example, organizational structures in the Cold War Era were more stable and identification of important people or leaders in the Russian hierarchy was a relatively stable phenomena. Now, terrorist organizations are a very adaptable, resilient enemy and identifying critical people or leaders is a much trickier, on-going problem. Shifts of critical personnel in a network centric organization is an important evolutionary problem to understand.

1.3 Shifts of Critical Personnel: Prior Work and Current Focus

Traditional social network analysis has identified critical personnel through the static examination of organizational structure (Bonacich, 1987; Krackhardt, 1987; Brass, 1984; Blau & Alba, 1982; Freeman, 1979)[2]. Although these studies provide meaningful insight to identifying critical personnel at a particular point in time, the cross-sectional nature of the data precludes any attempt to understand and identify shifts of critical personnel over time, especially as the environmental setting and operational conditions change. This only provides limited insight into the process of network change and the nature of network centric organizations. Therefore, we are interested in how a range of operating conditions affect shifts of critical personnel within an organization.

These shifts, as apparent, are evolutionary and require dynamic, longitudinal methods of analysis. Therefore, process needs to be accounted for in the methodology and added to social network theory (Carley, 2003; Kanter & Eccles, 1992). This work takes a serious view of this need and incorporates process in both methodology and theory. The decision to take this route was not only influenced by the academic need for such but also because leaders have a real need for process in the practical application of network research (Kanter & Eccles, 1992).

2. Modeling Shifts of Critical Personnel: Operating Conditions, Stressors and Change

Change and uncertainty create stress on an organization. Stress is something that all organizations face (Perrow, 1999). The variety and strength of stressors induce a range of operating conditions which confront the organization and it is reasonable to conjecture that operating conditions affect shifts of critical personnel. More specifically, low stress operating condition may result in fewer shifts whereas high stress operating

[1] Although the author recognizes that organizational action also contains feedback to the environment and contributes to changes there as well, it is not the focus this research and lies outside the bounds of this study.

[2] There are a few studies that have analyzed networks and critical personnel change over time (Sampson, 1968; Burkhardt & Brass, 1990; Carley, 2003; Johnson, Boster, & Palinkas, 2003). But these and the other studies looking at shifts of critical personnel only study the effect of one factor. The partiality of results makes it difficult to develop an overall theory.

conditions may result in many shifts. Accordingly, it is meaningful to understand the evolution of critical personnel shifts across the range of operating conditions.

Lin and Carley (2003) describe three general types of stress that organizations face: external stress, internal stress and time pressure. External stress originates from the external environment. An environment with rapid change and uncertainty is an example of external stress. Network centric organizations are used in these environments and are considered an advantageous design for dealing with external stress. Internal stress originates from malfunctions in organizational operating conditions. Examples of internal stress are communication barriers, turnover and agent unavailability. This forces sub-optimal conditions for communication and learning within an organization. Time pressure constrains rationality. Under time pressure, organizations may communicate and learn based on limited knowledge. This also forces sub-optimal conditions for communication and learning in organizations. These three stressors can all be simultaneously present in the organization to varying degrees at a given point in time (Lin & Carley, 2003).

Following the work of Lin and Carley, we modeled each type of stress as well as the simultaneity of stressors to represent a range of operating conditions. Stressors were modeled at the organizational level and equally affect each agent concurrently within the virtual experiments. The organizational level is the level of interest for this particular study. Individual differences in reactions to stress would represent stress at the individual level and it is assumed that such individual differences would wash-out at the organizational level[3].

2.1. Construct

Each of the stressors were modeled in Construct. Construct is a multi-agent network model for the co-evolution of the socio-cultural environment (Carley, 1990, 1991, 1999; Schreiber & Carley., 2004a; Schreiber & Carley, 2004b; Schreiber, Singh & Carley, 2004, Hirshman, Carley & Kowalchuck 2007a; Hirshman, Carley & Kowalchuck 2007b; Hirshman, Martin & Carley, 2008). In the model, agents go through an active, adaptive cycle where they choose interaction partners, communicate, learn knowledge, change their beliefs about the world, and adapt their networks based on their updated understanding. Knowledge network data is input into Construct to initialize the model with a real-world representation of an organization. The knowledge network is 'who knows what' in the organization and knowledge is defined into categories that are relevant to that particular organization. For detailed description of Construct see the above referenced publications.

[3] Individual level stress could not be modeled even if this were a level of interest because this data was not available to collect from the real-world organization.

External stress was modeled as a dynamic task environment whereas the knowledge an organization needs to learn changes at varying rates. In Construct, the external environment represents the task environment of the organization. The agents interacted with the external environment and learned bits of task-related knowledge. The agents then interacted with each other and engaged in task-related communication. Change in the environment occurred by changing the value of the knowledge bits. Agents then had to learn about the change in order to maintain or improve organizational learning. The rate of change in the task environment was probabilistic and occurred at random. For example, when the rate of change was 25% then each knowledge bit had a 25% probability of being changed each timeperiod. A random roll of the dice determined if a particular knowledge bit was changed. The rate of change in the external environment indicated the level of stress. For example, the higher the rate of change the higher the external stress faced by the organization.

Internal stress was modeled as intermittent availability whereas agents are unavailable for interaction and subsequently task-related communications are constrained. The percentage of unavailability indicated the level of stress. For example, the higher the percentage of unavailability the higher the internal stress of the organization. Again, this stressor was modeled at the organizational level and affects each agent concurrently

Time pressure was modeled using an information processing approach based on selective attention. The following reasoning was applied. Stress causes a rise in arousal (Eysenck, 1967) which then causes selective attention of knowledge (Easterbrook, 1959; Matthews, Davies, Westerman, & Stammers, 2000). Selective attention narrows the amount of knowledge that is considered when communicating. Therefore, learning under the influence of time-pressure is cognitively constrained. This approach is consistent with organizational theorists in that individual stress is the enemy of rationality (Simon, 1947) and reduces the search for alternatives (Staw, Sandelands, & Dutton, 1981). In Construct, agents under time pressure only consider a portion of the overall knowledge they possess when communicating. The portion of knowledge was determined by 1 minus the selective attention effect. In other words, if an agent knows 10 bits of knowledge and they have a selective attention of 20% then the agent only considers 80% or 8 bits of their knowledge when selecting a bit to communicate. A random role of the dice determined the knowledge bits which were selected for consideration. The level of selective attention indicated the level of stress. For example, the higher the level of selective attention the higher the time pressure and cognitive constraint on the knowledge considered for communications.

The model was tested to ensure that the stressors were working correctly. Each organizational stressor decreased organizational learning significantly. Higher levels of stress within each stressor significantly decreased performance as compared to the next lower stress level. And the effects of the stressors were comparable to each other. Confidence interval tests were used to test for significant effects.

3. Methodology

3.1 Data

The network centric organization under study was the Battle Command Group. The Battle Command Group is comprised of decentralized, distributed and highly interdependent units performing joint and coalition operations. The particular organization studied consisted of one-hundred and fifty-six people. Data collection occurred during the beginning phases of a wargame exercise and Cross-sectional data was collected on the communication and the task networks of the organization. The task network consisted of fifty-one task nodes and was used as a proxy for the knowledge network in Construct. The task network is an appropriate proxy for the knowledge network because these tasks are actually written products which relay information about the operational environment. Examples of task products include maneuver estimates, intel synchronization plans and support orders. In addition, the task network representation produced initial agent interactions in Construct that were validated against the actual communication network of the organization (Schreiber & Carley, 2007).

3.2 Experimental Design

Table 1 presents the experimental design for the shifts of critical personnel virtual experiment. The network was evolved over 250 timeperiods and each result was obtained using a Monte Carlo technique 25 times.

Variable	**Description**	**Values**
Organization	Organizational Model	Battle Command Group
Dynamic Environment	External Stress	No change 25% rate of change 50% rate of change 75% rate of change
Intermittent Availability	Internal Stress	Always available 25% unavailability 50% unavailability 75% unavailability
Selective Attention	Time-pressure	No constraint 25% selective constraint 50% selective constraint 75% selective constraint

Table 1: Experimental Design for Shifts of Critical Personnel

The focus for this virtual experiment was on the outcome of structural change in terms of critical personnel. Agent interaction patterns produced by Construct were averaged over the Monte Carlo runs and analyzed to determine which agents were critical. The agent interaction patterns correspond to organizational communication networks and as noted before, the initial agent interactions in Construct were significantly similar to the real communication networks. Therefore the set of critical agents in Construct at timeperiod 0 represent the initial set of critical personnel in the organization before changes and adaptations occur.

Agent criticality was determined by two factors – social network measures of centrality and measure ranking. Centrality was selected because this family of measures is most commonly used for identifying critical personnel in communication networks. The following centrality measures were calculated: betweenness, eigenvector, information and total degree. It is customary for these measures to be correlated and a correlation analysis verified that this was the case. Therefore, only one measure was used to represent criticality – eigenvector centrality. Eigenvector centrality was selected because it had the highest level of significance among all the correlations but any of the measures would serve the purpose.

The second factor in determining agent criticality was measure ranking. The top five agents in terms of highest centrality value were defined as critical. These five agents make up the critical set for each timeperiod. The decision to use five was basically arbitrary as there is no a-priori basis for determining how many agents within a measure are considered critical. Five was chosen because it has been commonly used in the applied work I have done within organizations.

Two types of change in criticality are measured and analyzed, total change and unique change. Total change measures the number of changes that occur to the composition of the critical set over time. This measure was calculated as follows. The critical sets for each adjacent comparison timeperiod were contrasted and a change was recorded for each difference between the sets. For instance, if the sets of agents being compared were {1,2,3,4,5} and {3,4,5,6,7} then two changes would be recorded as there are two differences between the sets. The total number of changes across all comparisons equaled the number of total changes. One note - this measure accounts for the situation when an agent was in the critical set, fell out of the critical set, and is now back in the critical set. It counts this as a change.

Unique change measures the number of times a new agent enters into the critical set. A new agent is defined as someone who has not previously been in the critical set. This measure was calculated as follows. The critical sets for each comparison timeperiod were joined to make one union set. The difference between the number of agents that comprise the union set and five (the maximum number of critical agents per timeperiod) equaled the number of unique changes.

Both types of change were measured and analyzed to see if operating conditions affected them differently. For instance, it would be reasonable to presume that many different operating conditions induce high amounts of total change but only a few induce high amounts of unique change. Unique change would be particularly interesting to explore as there are many more agents assuming critical roles and this could have important organizational implications.

Comparative analysis for calculating the total change and unique change measures occurred between timeperiods 0, 50, 100, 150, 200 and 250. The Battle Command Group knowledge network had enough fidelity such that structural changes in Construct needed to evolve over several timeperiods. The above timeperiods were chosen because they allowed enough duration for change to occur between comparisons and because they provided even spacing for calculating change.

The purpose of this study was to build theory about the effects that various operating conditions, as represented by stressors and stress levels, have upon changes in critical personnel. It was previously determined that there were a sufficient number of runs within the virtual experiment to gain significance and obtain a good estimate of the stressor effects. Therefore, the next step in the analysis was to determine the direction and strength of the relationship between the stressors and structural change. To make this determination, the main effects of the stressors were plotted and multiple regression was performed. The standardized beta coefficients from the multiple regression analysis were used to assess the relative impact of the stressors. These analyses were completed for both total change and unique change.

4. Results and Discussion

The Battle Command Group experiments resulted in a range of 1–9 for total change and a range of 1-6 for unique change. Figure 1 shows the Battle Command Group main interaction plots for both total change and unique change based on data means. Several things are notable. First, the dynamic environment lead to more shifts of critical personnel when there were moderate or high rates of environmental change. Second, intermittent availability increasingly constrained the shifts of critical personnel as the stress level went up. Third, selective attention reduced the shifts of critical personnel but levels of stress beyond 25% had less of an effect. The low average knowledge per agent in the Battle Command Group, which is due to data being collected at the beginning of the exercise and limited scenario training for the participants, explains the plateaus.

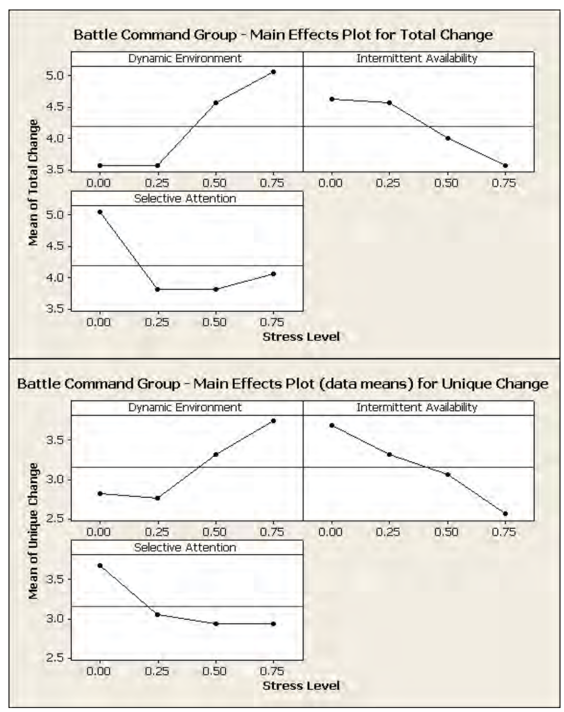

Figure 1: Main Effect Plots for Total Change and Unique Change

For the dynamic environment condition, the 25% rate of environmental change does not increase shifts of critical personnel over the static environment. The low average knowledge in the organization meant that expertise was just forming. As the agents learned and began to gain expertise then considerable shifts of critical personnel occurred, even in the baseline condition. The 25% rate of environmental change was not enough change to induce greater shifts of critical personnel over the baseline. It took higher rates of change to do that.

For the selective attention condition, increased stress levels did not further moderate shifts of critical personnel. The lack of training already resulted in low and constrained overall knowledge. Additional cognitive constraint beyond the 25% stress condition had little effect because of this.

Table 2 presents the results of separate multiple regression analyses for total change and unique change. These results show that intermittent availability had a stronger impact on constraining both types of change as compared to selective attention. These results also show that the dynamic environment again had a stronger impact on total change relative to the other stressors. But this is not the case for unique change as the dynamic environment had a similar strength of impact to that of intermittent availability.

Battle Command Group *Total Change*		**Battle Command Group** *Unique Change*	
Regression Coefficients		**Regression Coefficients**	
Variable	*Standardized Coefficient*	*Variable*	*Standardized Coefficient*
Dynamic Environment	0.333	Dynamic Environment	0.311
Intermittent Availability	-0.227	Intermittent Availability	-0.334
Selective Attention	-0.182	Selective Attention	-0.219
Model Fit Adj R-Spare – 15.6%		**Model Fit** Adj R-Spare – 21.8%	

Table 2: Standardized Coefficients from the Multiple Regression Analyses for Total Change and Unique Change

4.1 Shifts of Critical Personnel – Theory

Theory is proposed about the shifts of critical personnel in network organizations based on the Battle Command Group results. The dynamic environment led to increased shifts of critical personnel as the rate of change in the task intensified. This suggests that re-identification of critical personnel in network organizations should be an on-going activity. A lack of re-identification, especially in volatile conditions, could pose a risk to network organizations. Particularly when strategic decisions such as task assignment, group formation, and personnel retention are made from an offensive perspective or targeting and recruitment are made from a defensive perspective.

The ability of network organizations to exhibit overall structural flexibility in volatile environments is already set in theory. In fact, overall structural flexibility was a key characteristic influencing the use of the network forms by the organization under study. This result builds upon existing theory by proposing that critical personnel substructures also exhibit flexibility during times of change.

> *Proposition 1: Shifts of critical personnel are positively related to the rate of environmental change*
>
> *Proposition 2: Shifts of critical personnel can pose a risk to network organizations in dynamic environments when re-identification has not occurred and strategic personnel decisions need to be made*

The results demonstrate a clear negative effect for intermittent availability and selective attention on structural flexibility. (Note: intermittent availability represents communication network constraints and selective attention represents cognitive constraints.) Especially at high levels of stress, these stressors limited the number of shifts that occurred within the critical personnel substructures.

This can pose a significant risk to a network centric organization if such flexibility is an advantage for dealing with change. For example, this could slow the integration of diversity or circumvent resiliency. It could slow the integration of diversity when a situation calls for a variety of expertise that is different than previous conditions and those experts do not step up to enact critical roles. It could circumvent resiliency when current critical experts become unavailable or overtaxed and redundant expertise does not shift into the critical role. Moreover, limitations to the number of agents who can assume critical roles, as in unique change, could pose a risk by restricting the development of expertise. Fewer agents can assume critical roles that give them valuable experience.

Proposition 3: Shifts of critical personnel are negatively related to communication network constraints and cognitive constraints.

Proposition 4: Communication network constraints and cognitive constraints can pose a risk by modifying the number of flexible responses, in terms of critical personnel shifts, exhibited by a network organization in a dynamic environment. This is a risk only when such flexible responses are advantageous and sufficient to dealing with environmental change.

To clarify proposition 4, it is recognized that an occurring shift, even when a shift is needed, is not in and of itself sufficient to ensure an effective response. Shifts could occur that are counter to an organization's intended objective. For example, a situation may be misinterpreted and the wrong agent may assume a critical role. In this case, a necessary shift could be insufficient and result in a risk to the organization.

Intermittent availability had a stronger impact on shifts of critical personnel than did selective attention, as evidenced by the standardized beta coefficients from the multiple regressions. This implies that, at the organizational level, communication constraints are a slightly bigger risk to critical personnel shifts than are cognitive constraints.

Proposition 5: Communication network constraints are a slightly larger risk to shifts of critical personnel in network organizations than are cognitive constraints

4.2 Normative Implications

The proposed theories on critical personnel risks have several normative implications for the network organization under study. Some normative implications are discussed below.

The Battle Command Group should re-identify critical personnel often. Observations of this organization during the wargame exercise noted rapid changes to the operational scene when the exercise was in full tilt. The theory developed in this thesis suggests that considerable shifts of critical personnel will occur during these times. Re-identification will keep the organization current on who is critical. The organization can then make use of these critical personnel in the present situation and this can provide benefits. For instance, critical personnel may improve staff decision-making. Critical personnel who are high in betweenness or degree centrality tend to accumulate knowledge which leads to high situational awareness. Integrating these people into the decision loop can provide the staff with a better understanding of the present situation. In other words, current critical personnel can contribute to the observe and orient processes of the OODA loop. They can also contribute to the decision and action processes as well but in any case their inclusion in the loop may serve to improve decisions.

In addition, critical personnel can be used to improve information flow and the rate of learning in the organization. Observations also noted considerable communication network complexity during times of rapid change. Communication network complexity can slow the rate of learning. Central persons in the communication network serve as focal points or conduits for communications. Commanders can send and receive information through these central agents thereby taking advantage of shorter path lengths and possibly decreasing the number of paths. This serves to reduce communication network complexity and also speed the flow of information. This can also serve to more efficiently integrate the information that is flowing through the organization. Of course, critical personnel can shift during times of rapid change and an awareness of current critical personnel is needed for this strategy to be effective. This is another reason why re-identification is important.

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